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EDITORIAL

VETERINARY EDUCATION

Two important announcements concerning veterinary education in this country have just been made. One concerns the University of Liverpool, to which an Order under Section I of the Veterinary Surgeons Act (1948) has been made by the Privy Council in consultation with the Royal College of Veterinary Surgeons. This means that now the University of Liverpool has full powers to teach and examine students for a degree in Veterinary Science and Medicine, which, subject to certain conditions and the payment of certain fees, will carry with it the right to have the graduate's name on the Register of the Royal College and for the graduate to style himself a Member of the Royal College of Veterinary Surgeons. This means, further, that the Royal College will shortly cease to carry out examinations for veterinary students at the University of Liverpool. Liverpool is to be congratulated on being the first University to come under the working of the 1948 Act. Doubtless the other Universities at which students are reading or are to read for degrees in Veterinary Science will have a similar Order given to them in due course.

The Royal College will, of course, continue to act as an Examining Body so long as students are presented by Colleges or Universities for examination, but one can foresee in the not too distant future the end of the Royal College as an Examining Body. It will, of course, take on the functions laid down for it in the Act, viz., visiting Universities for the purpose of seeing the facilities for teaching and attending at examinations. This must be a proud occasion for those who have striven for University education for veterinary students leading to degrees in Veterinary Science which would carry with them registration by the Royal College, without the necessity of submission to double examinations in the different subjects.

While on the subject of the University of Liverpool, we note with much pleasure the award of the Honorary Degree of Doctor of Veterinary Science to Fred Blakemore, Professor of Veterinary Medicine in the University of Bristol,

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who qualified M.R.C.V.S. from Liverpool. We congratulate him on this well-merited award and express our happiness that the University of Liverpool has recognised the worth of one of its old students. Those who know him well realise his sterling qualities and how much he has already done for the profession.

The second announcement concerns the University of Cambridge: Major L. P. Pugh has been appointed Professor of Veterinary Clinical Studies. We congratulate Major Pugh on this appointment and we are happy that the University has made such a wise choice. For many years we have been looking to the University of Cambridge to inaugurate a degree in Veterinary Science. Many difficulties have been encountered in the attempts to bring about this position: now, however, the die is cast and the necessary steps are being taken. Under the guidance of Professor Beveridge and Professor Pugh we are quite satisfied that the University of Cambridge will play an important part in the education of future members of the profession.

These announcements are especially welcome at this time when the services of the profession are in such great demand. Throughout the whole world there is a demand for more and more veterinary surgeons: the need for well-trained men and women is urgent, and the linkage with the Universities is a clear indication of the spirit with which this country is entering into the supplying of this need. We will follow with much interest the part which the Universities play in the training of the future members of the profession: there is now a golden opportunity to show the benefits which we believe can accrue from a University training and from the close association of our students with men and women undergoing training in the many subjects for which a University is responsible.

GENERAL ARTICLES

SUBACUTE BACTERIAL ENDOCARDITIS WITH PULMONARY EMBOLISM IN A HORSE ASSOCIATED WITH SHIGELLA EQUIRULIS

By J. R. M. INNES,[1] J. BERGER,[2] and J. FRANCIS.[3]

Introduction

INFECTIVE endocarditis (excluding rheumatic endocarditis) and its clinical and pathological sequelæ account for much of human cardio-vascular disease (see Boyd [1947], and Hadfield and Garrod [1944]). In man a variety of micro-organisms may be implicated in the ætiology, such as *Streptococci, Pneumococci, Gonococci, H. Influenzæ,* and rarely *Brucella, Erysipelothrix,* and *Actinomyces.* In the acute type the course is less than six weeks and the primary focus of infection may be unmistakable, e.g., furunculus, osteomyelitis, or puerperal sepsis. The main pathological characteristics are the exuberant friable vegetations which destroy the valves, chiefly those on the left side of the heart. Embolic abscesses may be formed in many parts of the body and the general picture at death may be that of pyæmia.

In the subacute type the course may be from two months to years; the clinical manifestations embrace continued fever, evidence of multiple embolism, enlargement of the spleen and a positive blood culture; until the advent of the antibiotics prognosis in fully developed cases was almost hopeless, and, as Boyd intimated, the heart beat muffled marches to the grave. In about 95 per cent of cases the causative organism is *Streptococcus viridans.* The lesions comprise large, crumbly vegetations along the line of contact (proximal aspect of cusp) of the valve, but may cover it and spread on the mural endocardium. Some calcification indicative of attempts at healing may occur. The mitral valve is mostly involved, the aortic next, while the pulmonary valve is rarely affected. The vegetations are composed of amorphous masses of fused platelets and fibrin with clumps of bacteria buried or on the surface; there is infiltration by mononuclear cells, but a remarkable absence of polymorphonuclear leucocytes; no bacteria are found in the tissue where the cells lie, and there are no cells among the bacteria; fibroblastic proliferation may be present deep in the lesion where there is some reparation. Embolic lesions are frequent but are non-suppurative, in contrast to those in the acute type, while large infarcts due to blocking of medium-sized vessels may be present in the spleen and kidneys. In the latter another specific lesion may occur, viz., a focal embolic glomerulo-nephritis (Lohlein). The pathogenesis is not fully established; one concept is that bacterial

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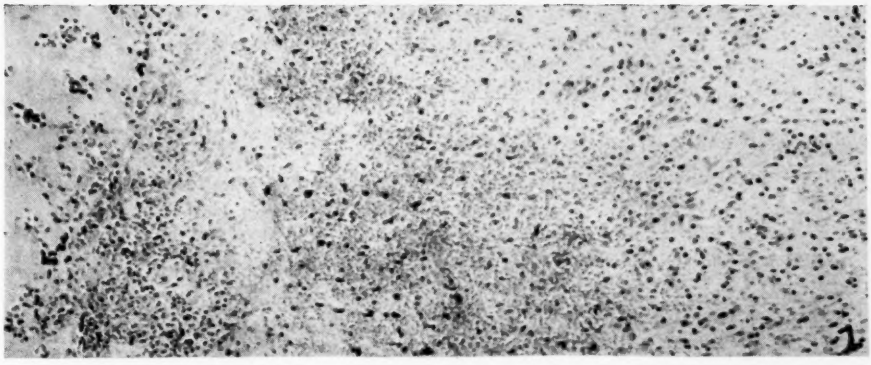
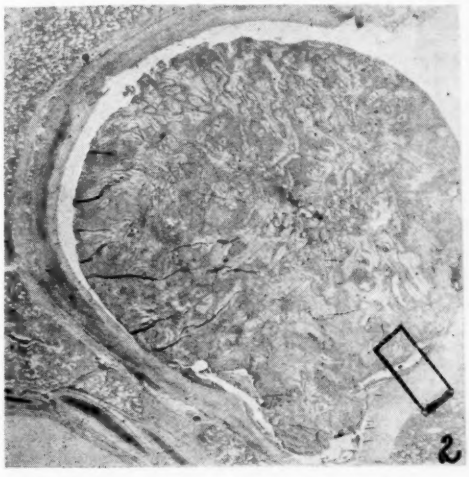
emboli in vascularised valves are responsible; the other prevailing view is that it originates by direct bacterial implantation in a predisposing lesion of small crevices and pockets of valves. The primary source of the infection may often be dubious, but the mouth and throat are often suspect. Those integral features in such types of human cardiac disease, summarised above, serve as a basis for comparison with animal conditions.

The general incidence in animals of endocarditis might be lower than in man for various reasons. There are not the same great variety of causative pathogenic organisms with a specific predilection for attack upon valves, or endocardium, in animals. Further, in assessment of incidence of diseases of this nature there is always the fact that only a small percentage of dead domestic animals reach the post-mortem table of the veterinary pathologist when full pathological and bacteriological examinations can be made. This applies whenever mortality of animal diseases is considered, for most figures deal substantially with selected sources of the animal population. Valvular disease as a whole is said to be most common in dogs over a year old; Cadiot found it present in 5 per cent of dogs, and Johne saw "endocardial changes" in 4.3 per cent; next to dogs in frequency is the horse, then cattle, while in sheep, goats and cats "valvular disease" is rare; the specific form in swine erysipelas occupies a special category (see Hutyra, Marek and Manninger [1946]), and Joest [1921-37]). Much more precise data are required of the pathology, correlated with signs and symptoms determined by modern clinical diagnostic methods; it is doubtful if, as yet, the diseases can be divided into acute, subacute and chronic forms retaining the meaning of these terms as used in human medicine.

In lower animals the anatomical appearances of ulcerative and vegetative valvular lesions are like those seen in man. There seems to be an inexplicable proclivity for the disease, as a whole, to occur on the right side with some predilection for the semilunar valves (Nieberle and Cohrs [1949]); when present on the left side embolic complications may also ensue. The records of one of us (*J.R.M.I.*), include two canine cases (Streptococcal), in one of which there were large vegetative lesions on the aortic valves with mural spread and with non-suppurative embolic lesions and infarcts in the kidneys; in another case, with an acute seven-day illness, there were ulcerative lesions of the tricuspid valves with mural spread and an accompanying interstitial nephritis—lymphocytic and histiocytic. This latter complex has been also recorded by German writers, as also the association of "contracted kidney" and uræmia in dogs with endocarditis (see Nieberle and Cohrs). According to Wright (1950), a valvular disorder of fibrous thickenings may affect the left atrioventricular valve, particularly in brachyocephalic dogs, e.g., Pekingese; this is of unknown ætiology, but Wright considers it may be a hypertrophic response to overstrain. Marked variation in the appearance and thickness of the free edges of valves (and *Corpora Arantii*) may be seen in old dogs of different breeds. Prudence would thus be required before the inclusion of such fibrous thickenings as indicative of endocarditis, for there is no evidence that these are in fact residual of bacterial, or other, forms of inflammation. The occurrence and incidence of sclerosis and





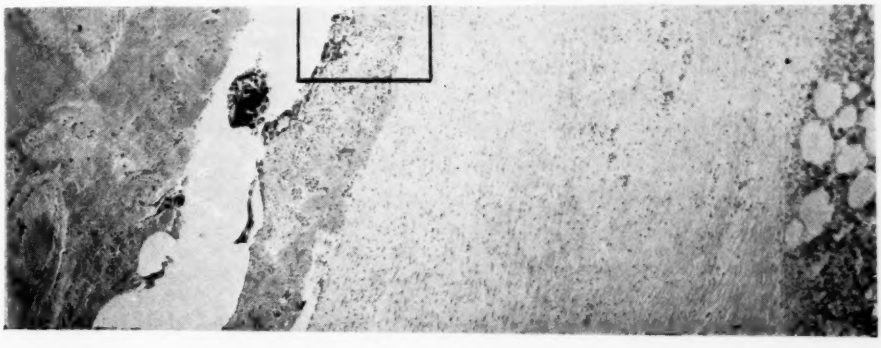


Fig. 1

Valvular lesion, horse. Showing from left to right (vegetation), fibrin necrosis, hæmorrhage, and fibroblastic proliferation (H.E. x 125).

Fig. 2

Pulmonary embolus and adjacent lung. Obturating clot adherent in places; space between clot and arterial wall is artefact (H.E. x 5).

Fig. 3

Area marked in fig. 4 showing clot adhering to wall with cellular infiltration (H.E. x 187).

Fig. 4

Area marked in fig. 2 showing, from left to right, structureless clot, an artefact space, clump of cells and bacteria, adherent clot, arterial wall and on extreme right some lung tissue (H.E. x 55).

calcification of valves in old animals, comparable to that seen in old people, is unknown.

A variety of organisms (different from those in man and usually non-pyogenic) may cause malignant endocarditis in animals. The commonest might be the *Erysipelothrix* causing the verrucose endocarditis in chronic swine erysipelas; 676 cases were found in 16,000 pigs which had died from swine plague; the same organism has been occasionally identified in equine endocarditis. *C. pyogenes* appears to be a common cause in cattle, but only occasionally in sheep and pigs, while streptococci have been implicated in cattle, pigs and dogs. Other organisms less freqeuntly isolated include *E. coli* and staphylococci. *Mycobacterium tuberculosis* must be rarely involved and the endocarditis would mostly arise as a direct extension of a process initiated in the myocardium and never exclusively the valves. The same might apply in foot and mouth disease, in which the virus may cause a non-specific necrotising myocarditis in cattle, and the same may occur in Clostridial infections of cattle and sheep; hæmorrhagic necrotising lesions have been seen by one of us (*J.R.M.I.*) in the myocardium and endocardium of " pulpy kidney " disease of lambs.

The infections in remote anatomical parts which have been said to cause bacteriæmia and to produce valvular lesions include metritis in cattle and joint and umbilical infections in young animals.

Clinical History

Only the relevant data are given. A 14-month-old hackney colt had a history of strangles some months previous to the terminal illness, with submaxillary abscesses which had ruptured and healed. It recovered and was in good health until 2.8.46, when it was seen lying down, was able to rise, but ate little. There was no sweating or other signs of *high fever* in the subsequent nine days of life, although the temperature was above normal limits. The gait was very slow and it could not be made to trot or turn sharply; it tended to lie recumbent on its side. Sodium sulphamezathine (i.v.) was given on the 1st, 2nd, 5th, 6th and 8th days of illness; the initial injections were followed by a fall in the temperature. By the 8th day there was gross deterioration in condition, and the animal died during the night of the 9th day. It was not seen during the last day of life.

Pathology

Post Mortem Examination.

(a) *Macroscopic findings.*

It was only possible to make a thorough examination of some organs brought back from the knackery, although no macroscopic lesions were observed in other viscera which were superficially examined there.

Heart.—There was no gross abnormality visible externally and no pericardial effusion or inflammation. The right side showed some slight dilatation. On opening the cavities the prominent feature was the voluminous, polypoid vegetations, of the semilunar valves, in part extending along the pulmonary

artery; the lesion implicated one cusp and perhaps had originated on the proximal aspect, but overlapped the free border and covered the whole cusp. The vegetative projection into the lumen of the pulmonary artery was a firm yellow, conical, fibrinous mass, whereas the irregular excrescence pouting into the ventricle was dark red and crumbled easily. There was no mural spread. The bifurcation of the pulmonary artery was not obstructed. At a short distance from the division, in a main branch (left about 2 cm. in diameter), the lumen was obturated by a 5 cm. long embolus which was partly adherent to the lining. All other valves and the myocardium were normal. No changes were present in the intima, or walls, of the remaining arterial or venous trunks, apart from coincidental parasitic endarteritis of the coeliac artery.

Lungs.—Some bullous emphysema was present in the cranial lobes; scattered throughout the lungs were wedge-shaped, dark red subpleural areas (infarct-like) alternating with ochre-coloured lung substance.

Liver.—No lesions were seen in the portions examined.

Spleen.—The substance was diffluent, dark and like septic "splenic tumour."

Kidneys.—A single (1 cm. diameter) encapsulated abscess was present in the right kidney without other alterations.

(b) *Histological findings.*

Sections included all areas of the valvular lesion from the appendicular edge of the vegetation to the attachment of the valve and muscle. The free edge was largely fibrin with small clumps of polymorphonuclears and lymphocytes and large masses of bacteria. The part adjoining myocardium and artery showed a luxuriant proliferation of fibroblasts, numerous thin-walled capillaries and much histiocytic and lymphocytic infiltration (Fig. 1). Between these two extreme zones there was hæmorrhage, cellular infiltration and prominent bacterial clumps. The myocardium directly adjacent showed some destruction of fibres, but at a short distance away was normal.

A low power view of the obturating lesion in the pulmonary artery is shown in Fig. 2. The embolus was partly adherent to the wall; the centre was largely fibrinous clot and structureless with scattered massive bacterial aggregations and few cells. The intima had been mostly destroyed and was coated with fibrin where not adherent, and there was some histiocytic and polymorphonuclear infiltration, quite intense in places, extending to the adventitia; there was marked periarterial hæmorrhage with much blood pigment. The appearances of the lung varied in different parts; many areas were quite normal; other regions were literally stuffed with blood—in vessels and free in the alveoli; many small vessels contained fibrinous thrombi; there were areas of collapse and pneumonic foci usually associated with the latter. There were no lesions in the kidney, apart from the abscess visible macroscopically. The liver showed some degree of central ectasia of sinusoids, no necrosis, little fat and moderate hæmosiderosis. The spleen was grossly congested.

Bacteriology

A pure culture of Lancefield group C streptococci (animal pyogenes type) was isolated from the renal abscess. Examination of the sections of the pulmonary embolus and valvular lesion showed numerous aggregations of Gram-negative bacteria; pure cultures of *Shigella equirulis* were isolated from both lesions and need not be described. Edwards (1931) has given a description of this organism and reviewed the work on diseases produced by it.

Comment

The valvular endocarditis seen corresponds with what has been observed in many infective types; the degree of fibrosis indicates that it was not of brief duration before death. It certainly could not have had such a short span as to be related only to the terminal illness. Its anatomical character resembled somewhat the endocarditis in chronic swine erysipelas. On the other hand, the absence of gross dilatation of the right heart denotes that the valvular lesion was probably not of an extremely long-standing date. The presence of the lesion on the right side, involving the semilunar valves, coincides with what is the more common location in animals as compared with man. The pulmonary embolism must have been a relatively late development and clearly had arisen from separation of a bulky part of the vegetation protruding away from the cusp; this had not, however, been large enough to straddle the bifurcation. In man, pulmonary embolism arising post-operatively or as a complication of thrombo-phlebitis of the lower regions may obturate the bifurcation and may cause death from circulatory failure; if the patient survives for more than an hour or so, recovery is said to be likely. In animals the incidence of pulmonary embolism must be very much less than in man, and is rarely incriminated by the veterinary pathologist as a cause of sudden death following operations or as a sequel to phlebitis. Nieberle and Cohrs mention briefly its occurrence in a horse and a dog. In the present case the embolism may have had some part in hastening the animal's death.

The most important question concerns the ætiology of the endocarditis—*Shigella equirulis* being isolated in pure culture from the valvular lesion and the embolus and being seen in large numbers in the sections. This organism is pathogenic for horses, in which it usually produces a fatal septicæmia; according to Boyer (1919), it was isolated from the mouths of 8 per cent of horses examined. The endocarditis was not of an acute nature, and it is possible that some initial damage was done to the valve consequent to the attack of strangles. There are thus indications that the disease was subacute in type and perhaps comparable to what is seen in man, but, as far as we know, *Shigella* has never been associated with endocarditis in any of the lower animals.

Summary

(1) A case of subacute bacterial endocarditis in a horse is described which was characterised pathologically by exuberant, friable vegetations involving the

semilunar valves (pulmonary artery) and by a sequel of pulmonary embolism.

(2) *Shigella equirulis* was isolated in pure culture from the vegetations and embolus.

(3) The endocarditis was obviously not of short duration and might have been initiated in the first place by damage to the valve during the attack of strangles; the rôle of *Shigella* would seem undoubted as far as the terminal septicæmia is concerned.

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ELECTROPLECTIC ANÆSTHESIA IN ANIMALS AND MAN

By E. O. LONGLEY, B.Sc., M.R.C.V.S.

ALTHOUGH electricity has had increasingly wide use as an anæsthetic in abattoir practice for more than 20 years, and although its possibilities were immediately recognised, and received clinical trial and recommendation to the notice of the veterinary clinician by the late Sir Frederick Hobday as long ago as 1932, it has had to remain for the human brain-surgeon to give it serious clinical use as an anæsthetic, electroplexy being the form of anæsthesia recently introduced by Freeman (1949) for the two-stage operation of transorbital leucotomy in man. No doubt the particular advantage of electricity for the purpose in question is that this operation is prescribed as a last recourse in psychiatry, the patients are not always the best from the point of view of amenability, and anæsthesia by electroplexy may be applied in them with considerably less trouble than might attend orthodox anæsthesia. The analogy with the common enough veterinary situation will not escape notice. At all events it will be agreed that a practice that has come of age for purposes of anæsthesia in the abattoir, and which has met the requirements for this neurosurgery in man, cannot continue to deserve the total neglect of the practising veterinary profession.

The subject of electric anæsthesia and its literature has had previous review (Longley, 1949). The present paper is to discuss the possibilities, proper requirements for, and the prohibitions of the use of electroplectic anæsthesia in clinical veterinary spheres, and it has to be emphasised at once that the full possibilities are not knowledge. Experimental studies on the domestic animals are con-

spicuously few. Practical work has been perforce restricted for the present writer to the rabbit and the rat,* an experience supplemented by certain observations in the human clinic,† and of the use of the method for the slaughter of pigs, sheep, and the dog.

Nomenclature. The term *electrocplectic anæsthesia* (E.P.A.) is preferred by the writer to the more familiar *electric anæsthesia* and *electric stunning,* because it distinguishes a specific procedure and course of events. Thus E.P.A. is only one form of the varieties of electric anæsthesia possible. While electric stunning is not necessarily the same thing as E.P.A., because *anæsthesia* does not necessarily or reliably accompany the "stunning" process.

The possibilities with electricity are, as usual, multiple, and a first consideration becomes the duration of application of the current, which may be anything from a few milliseconds to hours. The term "electroplexy" (*plexis,* a blow) relates essentially to brief applications of heavy current for periods not exceeding fractions of a second to a few seconds, as is the specific procedure with which this paper is concerned. The more prolonged applications require separate consideration.

Consideration of Fundamentals

Before discussing them, certain contexual fundamentals require statement:—

(1) The passage of electric current of sufficient magnitude through the brain results in instantaneous loss of consciousness.

(2) With current of sufficient magnitude a typical course of events ensues, one feature of which is an epileptiform convulsion.

(3) The convulsion is followed by a period of complete muscular relaxation and anæsthesia, after which consciousness rapidly returns. The sequence is attended by total amnesia.

(4) Where the current takes effect but no convulsion ensues, consciousness may or may not be abolished, and in animals there are no known practical means of ascertaining the realities of the case. *The convulsion is thus the objective index and sole guarantee of unconsciousness.*

(5) From the point of view of fatality, the normal procedures are 100 per cent safe.

(6) The only significant clinical risk is that of skeletal injury. The contra-indications are few.

These several issues will now be examined.

(1) *Unconsciousness.* Consciousness has an essentially electrical background, and is seemingly dependent on the functional integrity and delicately balanced interplay of numerous component cerebral units. The impact of applied electric currents of sufficient magnitude stimulates indifferently every available neurone, this necessarily disrupting the normal functional pattern with

*Work made possible by a grant from the Universities' Federation for Animal Welfare, and conducted at the Burden Neurological Institute, Bristol.

†I wish to thank several medical authorities by whose courteous invitation this was possible.

the designated effect of instant unconsciousness. This is true for all forms of current, only with certain distinctions of detail.

(2) *Sequence of events.* The immediate effect of a pulse of current is a short, sharp jerk or "start" of the whole body, and appears to be common to all species. It occupies no more than a second or two and is characterised by dropping of the jaw and a tonic *flexion* of the hind limbs, which is of some physiological interest and might have considerable practical veterinary value. The fore-limbs exhibit rather extensor tonus, which is particularly marked in the domestic pig.

The immediate sequel is a phase of powerful generalised *extensor* tonus, with opisthotonus, etc., and lasting for a period of the order of 10 seconds, in man as in the rabbit.

This condition then merges into the clonic phase or convulsion proper, which is typically epileptiform and lasts for anything from some 15 to 30 seconds or slightly more (according to species as well as the circumstances), during which time it gradually subsides, yielding place to the phase of post-convulsive coma.

The convulsive sequel is determined not simply by the magnitude of the current, but by this in relation to the duration of application in time, and in accordance with the familiar strength-duration curve of neuro-physiology, which is as true for the intact central nervous system (C.N.S.), and the genesis of convulsions, as for the simple nerve-preparation in the laboratory (Hemphill and Walter, 1941; Harreveld, Plesset and Wiersma, 1942). Roughly speaking, the relationship is that the product *current* × *time* is a constant, i.e., for a given effect the necessary duration of the pulse of current is inversely proportional to the magnitude of the current, and hence in any given subject to the voltage.* The convulsive threshold of current may thus be defined as that current-level which, applied for however long, just fails to elicit a convulsion (the "rheobase"). It is also stated that for the realisation of a convulsion, at least two complete waves or cycles of the current must pass, e.g., with the current at 50 cycles per second (c.p.s.), as from the mains in this country, a minimum period of 0.04 seconds is demanded, and defines the low time-limit at this frequency. A single pulse or cycle at a sufficient voltage is stated to stun, but no convulsion will ensue (Hemphill, *et al.*; Liberson, 1945).

It is, of course, the density of the current and not the applied voltage that is the real physiological determinant, and thus as between individuals the efficacy of the application depends on three principal factors:—

(a) The resistance or, more correctly, impedence offered to the passage of the current by the tissues. This resides largely in the skin, and is a factor varying widely between individuals, but fairly constant in any one subject (Golla, Walter and Fleming, 1940). In all subjects the ohmic resistance of the skin

*Readers unfamiliar with electrical matters are reminded that the voltage (in units of volts) is the electrical pressure which drives the current (in units of amperes) through the resistance in question (measured in ohms). For a given fixed resistance the current is thus proportional to the voltage. For a given voltage the greater the resistance the smaller the current, and *vice versa*. This states Ohm's Law, which is not strictly true for alternating current (a.c.) such as is contextually the usual form of current concerned, but may be considered sufficiently applicable for the present purpose.

falls during the passage of the current after transit of the first few waves, by something between a third and a half of its previous value (confirmed also in the rabbit in the present studies). This fall in resistance is greater the higher the initial resistance, but it bears no predictable relationship to the latter (Golla, *et al., op. cit.*). Thus resistance measurements taken in advance (with a view to anticipating the voltage-requirements for any desired current-level, and as originally practised routinely in man) are futile and, as will be discussed, are in any case superfluous with a proper technique. The importance of this change in resistance is that it necessarily signifies an unstable flow of current, and hence less predictable results, unless the refinement to be discussed is introduced.

(b) The second determinant is individual susceptibility (idiosyncracy). For no ascertainable reason, individuals vary widely in their physiological susceptibility, and resistant subjects have a higher convulsive threshold than the average. This, like skin-resistance, is fairly constant in the individual, but is entirely unpredictable (and completely independent of the factor of skin-resistance (Golla, *et al., op. cit.*). Idiosyncratic levels are themselves subject to increase and decrease under the influence of chemical agencies (anti-convulsant and convulsant drugs).

(c) The third factor, represented more by experience with animals, is that of the size of the subject, on the implications of which very little is known. It is of little importance in man, where variations in cranial size are relatively small. But it might assume prime importance in clinical work in animals, as it does assume importance in the abattoir. It is quite certain that whatever the relationship may be, it is not *pro rata*; the various small laboratory animals have a requirement vastly in excess of the expectations on any such basis. But it is well established, and, indeed, a matter of commonplace abattoir experience, that large pigs and boars require considerably longer applications of the standard voltage for effect (*vide* Hobday, 1932; Dryerre and Mitchell, 1933; etc.). Such a feature is, of course, an *a priori* expectation, referable to the greater "dilution" of the current or, better, the relatively small area of brain stimulated (q.v.). But the issue may be complicated by factors (a) and/or (b), particularly the probability of higher skin-resistance, and requires careful correlation with these for its proper evaluation. It is the noteworthy and peculiar fact, however, that the average skin resistance in man according to Golla, *et al.*, the average skin resistance in the domestic pig as computed from the data furnished by Hill and McSwiney (1932), that in the cat according to the data of Rubinstein and Kurland (1948), and that in the rabbit as observed by the present writer, do not differ greatly (*ca.* 1,000 ohms). Such relative constancy of this factor would simplify technique in the comparative (veterinary) field and seem to be a particularly happy circumstance. This would be true with the use of existing methods, but, as will be seen in due course, a simple technical innovation makes the whole consideration of resistance very secondary.

During these various phases the respirations are in abeyance, being resumed as the stage of coma is entered. The general effect on blood-pressure is an increase, which (in sheep) may be two-fold (Clark and Tweed, 1932). At the

instant of shock the heart undergoes complete arrest, but resumes beating after this momentary pause, in marked bradycardia, which steadily gives way to acceleration, culminating in a sustained rate faster than the normal. No dysrhythmia is featured. These cardiac data were confirmed in the present studies on the rabbit, by electrocardiography. There is no question whatever of syncope.

If instead of a brief pulse of current the application is continued, a state of tonus is sustained for as long as the current passes, and if this exceeds the normal period of "spontaneous" tonus so as to extend into the phase of clonus, the normal convulsive pattern is modified by the imposed tonic condition and partly or completely suppressed (personal observation in man, the pig and the rabbit). If the application is continued beyond the normal phase of clonus, the subject will pass immediately on cessation into the phase of coma. Thus prolonged applications modify and can completely obscure the sequence outlined, true for a brief pulsed stimulus.

(3) *The period of anæsthesia or coma.* This varies considerably in duration. In man it is something of the order of five or more minutes, during which there is a progressive lightening of the effect. In the dog, Ivy and Barry (1931) report an average for all of 40 animals of slightly more than 2 minutes. With what they considered the optimal electrical conditions and a period of application of 15 seconds, this average became 4¼ minutes, with extremes of 2 and 12 minutes. Hill, *et al.* (1932), observed in pigs an average minimum of 1 minute and an average maximum of rather more than two minutes, according to the duration of application of the current (2.5-15 seconds, with non-linear increment at intermediate times). The duration observed by the present writer in pigs at the abattoir was of a similar order, as also by Hobday in his clinical trials (1932, 1935). In rabbits the period is less than a minute, but serial shocks were observed to result in an extension of this period and in marked sedation or quiescence after recovery. A similar sedative effect is recorded by Clark and Wall (1934) in cats, and is generally described in man.

It is evident that the duration of the coma is complexly determined by species-differences, electro-technicalities, and the time-factor, and is further discussed later.

The *amnesia* which attends the treatment is both retrograde and antrograde, extending from several seconds or more in advance of the shock, to the stage of recovery, and obviously offers to be as much value from the viewpoint of animal management as it is of recognised value in the human patient.

(4) The consequences of a *subconvulsive level* of current depend on the degree of inadequacy. As is pointed out by Hemphill, *et al.* (1942), an all-or-none response is implicit in the stimulation of nerve elements (centrally as much as peripherally), and any differences in effect must accordingly be ascribed to the *area* of the brain that is stimulated (both as regards neuronal number and kind). The average convulsive threshold in man is given as 60 volts, and with lower voltage "the area stimulated is so small that the patient may feel the shock and retain consciousness." In animals, the natural sequel to this

eventuality is escape behaviour. As recorded in the literature, the average convulsive theshold in the domestic pig is of the same order (60 V.). It follows that in unusually large animals and with a standard routine of application adapted to subjects of average size, the relative situation could be the same as that designated—the possibility of inadequate areal involvement.

If in man the dose is only just below the threshold, " recovery from the momentary unconsciousness is usually complete in a quarter of a minute . . . . If the stimulus is just threshold the onset of the convulsion may be delayed up to thirty seconds " (Golla, *et al.*, 1940). " Between the threshold shock and the delayed fit of slow onset there may be twilight state associated with motor-paralysis " (Hemphill, *et al.*). These data, based on human subjective experience, make it evident that the state of consciousness in animals after the treatment and pending the onset of the convulsion may not be inferred, either from their condition of immobility (" electric stunning "), or the state of the reflexes, etc., since in circumstances of motor-paralysis neither reflex nor voluntary motor-response is possible. This demonstrates the importance that attaches to the convulsion as a conclusive objective signal of unconsciousness.

Physiological basis. The neurophysiology underlying the electroplectic phenomena is most imperfectly understood and explained. The initial " start " effect has been ascribed to direct electrical stimulation of the precentral gyrus (Walter; Fleming, 1940), but this seems ill-related with its designated feature of tonic *flexion*. Indiscriminate stimulation of the motor-area should cause rather trismus, and an *extensor* tonus, on account of the dominance of the more powerful musculature, and it is significant that the latter is the characteristically different effect of electroplexy in chemically anæsthetised rabbits (personal observation). It therefore seems probable that the primary start has some less obvious and simple explanation and basis, possibly reflex.

The ensuing phase of rigid extensor tonus has been likened to the condition of decerebrate rigidity (Ivy and Barry, *op. cit.*; Frostig, Harreveld, Reznick, Tyler and Wiersma, 1944).

The change from this condition to that of the clonic convulsion has been offered explanation in terms of anoxic depression of the C.N.S. (Hemphill, *et al.*, 1941), but again it must be wondered whether this conforms with the evidence. It is true that convulsive patterns are in other contexts associated with central anoxic states, but this is by no means the rule, and the utmost caution is necessary in argument by analogy between the action and effects of electricity on the C.N.S., and those of chemical circumstances or agents. It may be wondered why an anoxia supervening so early and with such remarkable effect should lead to a phase of excessive and violent neuro-motor activity sustained without deterioration for a period often twice as long. Nor is it clear on first principles why anoxic depression should determine a state acknowledged by these same observers to be one of rapidly recurring cycles of maximal neuronal activity (or hyperactivity), actually *increasing* in its degree, during the course of the clonic episode and as revealed by their electro-encephalogram. Again a deterioration and hypoactivity would be the expectation. Nor do there in any

case appear to be very clear reasons for positing cerebral anoxia at this early juncture (10 seconds *ab initio*). The apnœa can play no part so early in events, and the heart is then beating well, while the evidence of several observers indicates an *augmented* rather than a depleted cerebral circulation. Moreover, observations made in the course of these studies in the rabbit demonstrated impressively that apnœa, combined with even *a 400 per cent slowing of the heart,* both sustained for a period of some 10 seconds, fails to evoke any sign of central dysfunction, let alone convulsions. Such are the immediate effects of exhibiting certain vapours (amyl nitrite, ethyl chloride, etc.) to the rabbit (see Figs.). Thus neither the respiratory nor the cardiac accompaniments of the electroplexy can be supposed to contribute materially to produce the effect in question.

Space forbids further discussion of this certainly involved question here, but it is suggested by the writer on certain *a priori* grounds that convulsions may be the necessary and inevitable sequel to the total or adequate stimulation in normal circumstances of an organ of the architecture and physiological mechanics of the brain, and may require no other explanation. And that anoxic depression and neuronal exhaustion, consequent on the excessive activity in any case eventuating, explain the change from the clonus to coma, rather than that from the tonic to the clonic condition.

These physiological issues are of more than academic interest. They govern the whole question of the anæsthesia in practical aspects, particularly its duration and the possibilities of any extension of this. It derives from the above that the duration of the anæsthesia is a matter of the functional recovery of the neurones from exhaustion. Such recovery is proverbially swift in nervous tissue, which would explain the universal brevity of the phase of coma at the same time as it would seem to set definite and narrow limits to the possibilities of its prolongation, which is in accordance with the available evidence. On the same basis it would be the expectation that the duration of the coma, which is the period for the re-establishment of complex neuronal functional patterns *in their correct phase relationships,* would be directly proportional to the size and complexity of the brain, of which also there are existing indications. Finally, they attract attention to the very special and indeed unique feature of the electric anæsthesias as distinct from all chemical varieties that it involves no unphysiological intoxication of the nervous system, a consideration with recommendations requiring no emphasis.

(5) *Safety.* No doubt much misunderstanding has in the past prevailed in respect of the lethal properties of electricity. The whole question is of particular veterinary interest and has an extensive literature, but is hardly due for detailed discussion in the present context, as the risk of fatality hardly arises. Summarising the situation as recognised, it may be said that, excepting only direct electric trauma, as by lightning or from powerful high-tension industrial sources of power, which can kill directly and are in a separate class, death by electric shock is always secondary to either syncope or asphyxia, both of which are contingencies remediable by the timely application of known resuscitatory

measures. Syncope results only where the current traverses the heart and institutes ventricular fibrillation. For this to occur the heart itself must lie in the direct path of the current, which precludes all possibility of this event in the present context, and leaves only asphyxial death for consideration. This is contingent on damage, either direct or indirect, to the respiratory centre, the former by paralysis, the latter by a secondary anoxia consequent on apnœa. The fatal consequence whether in association with fibrillation or apnœa, is always by anoxic depression of the C.N.S. As indicated, electric currents passing across the cerebrum for a short period must be of enormous volume to acquire directly lethal properties, which are contingent on an actual heating or searing effect and will require kilowatts of power, which is a possibility never arising with E.P.A.

Asphyxial accident may occur in any of three ways, viz. (1) by a faulty current-path mistakenly including the respiratory centre in circuit; (2) with a correct current path, by overdose in the electrical sense; (3) with overdose in a time-sense. The first of these hardly requires discussion, as in any case for the realisation of anæsthesia the current should traverse the cerebrum. The second contingency may be compared with the situation already discussed, where current of too low a value fails to stimulate a sufficient area of brain. So current of too great a value may stimulate or overstimulate too great an area, so as to include the respiratory centre in the medulla (Hemphill, *et al.*). This situation may be likened to overdose of the ordinary anæsthetics, and defines, in a similar manner, defective technique, but, as will be seen below, the margin is extraordinarily wide. In the present writer's observations this effect has never been seen. But it would appear to be the very exceptional occurrence in the human clinic that the patient does not resume respirations in the normal pattern at the conclusion of the convulsion, no less than that this situation never fails to respond to one or two compressions of the thorax. (It is stated in the technical literature on industrial accidents that the respiratory centre even gravely paralysed by electric shock will *always* recover with continued artificial respiration, damage by searing or supervening anoxia of course excepted.)

The third possibility will arise only with excessively prolonged applications of current and differs from the foregoing in principle. The respiratory centre is not directly affected, but suffers anoxic depression by reason of the rigid tonus including thoracotetany, which prevails for so long as the current passes. It is thus rather a "side-effect" of the anæsthesia than a direct one, and hardly requires serious consideration. It is exemplified in the first of Hobday's clinical assays of the method (1932) in three pigs of 28-score. In the first of these a preliminary application of 60 seconds provided anæsthesia of two minutes' duration, and was followed by two further applications of 45 seconds. These very excessive treatments proved fatal. The two remaining pigs survived more moderate treatment, though this involved periods of 45 and 30 seconds. The explanation for the need for such long applications is immediately available in consideration of the unusual size of these animals, and the strength-duration and other issues discussed earlier. Quite obviously the proper requirement here

was an increase in current. It may be laid down as probable that heavy current should never pass for a period exceeding 30 seconds, and that, so far as electroplectic practice is concerned, a primary need for applications of any such duration as 30 seconds indicts the electrical technique.

In further consideration of the question of safety it will be realised that electroplexy, since its introduction to psychotherapy in 1938 ("electroconvulsant therapy" or E.C.T.) has had employment many hundreds of thousands of times in man, is now in daily routine use in mental hospitals everywhere, and that no material risk of fatality is recognised. A voluminous literature has accumulated, and Cobb (1947), reviewing the situation, quotes Pullar-Strecker (1945) to the effect that in Great Britain up till 1944 some 10,000 patients had been treated (this signifies several times this number of *treatments*) with an overall mortality of six. As this includes the pioneering years of trial and error it is a report only the more impressive.

The voltage in use in the abattoir, and clinically by Hobday, is of the order of 70 volts r.m.s. (Hill, *et al.*, 1932; Anthony, 1932). Windle, Krieg and Arieff (1945), in a specific search for trauma to the C.N.S. and with negative findings, employed as much as 100 volts in *guinea-pigs*, this involving the passage of current up to 0.725 amperes for 6-12 seconds. This is the prolonged application of current at a level high for ordinary use even in man and the domestic pig, and an incomparably greater current-density is obviously attained in such diminutive subjects. Milligan (1946) has freely used for special purposes in man, an *average* voltage of 180 V. The voltage used in man for the surgical operation cited is 150 V. passing for 1 second, and this is delivered at least twice—at each stage of the operation—in the course of a few minutes. The present writer has employed serial shocks with current of the order of 0.3 amps. in rabbits (this being the maximum possible with the apparatus available), up to a maximum of eight successive shocks in 11 minutes, without adverse sequel of any kind, and has also witnessed the use for e.p.a. of the full mains-voltage across the head in dogs, from which recovery was still possible. But no doubt the most impressive data relating to safety is contained in the report of Rubinstein and Kurland (1948), on the lines of the repetitive treatment mentioned above. With a view to ascertaining the safety factor in this sense, these workers submitted 11 cats to repeated shocks *at 5 minutes' intervals*. In eight of the animals this was proceeded with till the point of death. The remaining three were permitted to recover. A progressive increase in the convulsive threshold was noticed in all cases. In the animals succumbing, an average of 58 such shocks and convulsions was recorded as fatal (minimum 30, maximum 87), occupying an average of 6 hours 4 minutes (minimum 4 hrs. 40 mins.; maximum 8 hrs. 19 mins.). Voltages up to 190 V. and currents of 0.475 amperes were employed.

Of the cats surviving, one received 40, a second 49, and a third 95 convulsive treatments, the maximum occupying 9 hrs. of time. "In spite of such intense treatment the rapidity of recovery, as judged by hopping and placing reactions, gait, feeding habits, preening and general observations, was truly

amazing. After 21 days these cats were behaviouristically indistinguishable from untreated controls." No macroscopic pathology of the brain was observed in any case.

These observers proceed to show that computed in terms of the *quantity* of electricity employed (coulombs), the M.L.D. was in no case in their series less than *x 57* the minimum convulsive dose (M.C.D.), to a maximum of *x 403*. This applies for the procedure of repetitive dosage, but may otherwise be likened to the *therapeutic index* of pharmacology (ratio of M.L.D. to the minimum effective dose). A more legitimate comparison with the pharmacological test-procedure is afforded by the result for single dosage (one electrical treatment), but no specific trials of this have come to the writer's notice, and limitations in the current obtainable from the apparatus available precluded its examination in the present studies. These same results in cats, however, signify that voltage and current levels more than four times greater than the original M.C.D. were not *per se* fatal. And the clinical work of Milligan in man indicates that increases exceeding three times the average convulsive dose are perfectly safe. Both observations indicate a therapeutic index certainly in excess of four. With continued application of current, the electrical dosage is obviously proportional to the time, and considering the index now in this sense, it has been seen that for current at 50 c.p.s., 0.04 seconds is the minimum convulsogenic period, while 30 seconds is less than the minimum lethal duration, so that here a safety margin exceeding *x 750* is indicated (at this standard frequency). These "indices" may be compared with the therapeutic index *for the safest* of the barbiturates, which is given as 2.5 (Sollman, 1936).

No further evidence will be adduced to justify the affirmation of a normal safety factor of 100 per cent, so far as primary electric fatality is concerned.

(6) *Side-effects*. These are, of course, featured with the ordinary chemical anæsthetics and can prove fatal, e.g., delayed chloroform poisoning, pneumonia. The most significant risk with E.P.A. would appear to be that of skeletal injury, which is recorded in man by various observers, and in the pig (Ducksbury and Anthony, 1929), generally in the form of crush-fracture, more rarely fracture of the neck of the scapula (pig). "Splashing" (pigs and sheep) is a second consideration.

The genesis of these lesions is obscure, but it would seem that in ways not well defined they are questions of technique; and that species-differences exist, on which latter basis the matter will be conveniently discussed.

In man. This aspect is considered first because it tenders the most evidence. The lesion involves the dorsal (thoracic) vertebræ and occurs at the point of greatest flexure, which detail is given ætiological significance by Fleming (*op. cit.*). It is commonly symptomless or causes only negligible and transient trouble (Cook and Sands, 1941). Its incidence is low, varying for different observers (but in terms of the foregoing absence of significant clinical signs, reports unsupported by radiography can obviously carry little weight). Nor according to these observers does it show any positive correlation with the muscular development or the violence of the convulsion. It is the concensus of

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opinion that it results from the primary jerk or "start" at the first impact of the current, and with forcible restraint of patients during at least this phase of motor-activity, as was customary in early days. With freedom in this sense its incidence approaches zero. These data recall veterinary lore and experience in avoiding crush-fracture in equines in ordinary anæsthetic practice, to which arching or flexion of the back, exaggeratedly tight hobbling, etc., are known to contribute.

Recent reports from America, in the context of the so-called "electro-narcotic therapy" in man, which involves the application of current at a high level for 30 seconds, state that the incidence is reduced to zero if the current is raised to its maximum in a period of some three seconds—the "glissando" technique—instead of allowing its sudden impact at the full voltage. On the other hand, Hemphill, *et al.*, report zero incidence over a series of 2,000 electroplectic treatments without this refinemant, which is, anyway, hardly applicable with durations of pulse of only fractions of a second, as here, in accordance with the usual practice of E.C.T. It is important to notice that there is no evidence that increase in either the applied voltage (two- or even three-fold) or in the duration of the application (at least 30-fold) increases the incidence of this complication, or introduces others, in man.

In the pig the high (5 per cent) incidence of such fractures observed in the early days by Ducksbury and Anthony (1929), and which led them initially to condemn the method for abattoir use, appear to have been associated with the use of excessive voltage and the manner of application of the electrodes. With the use of cranial electrodes only, the reduction of the voltage to its present low level, the figure fell to negligibility ("a fraction of 1 per cent") and the method was accordingly approved (Anthony, 1932). It is of interest that this authority (and slaughter-house lore) associates this consequence and the occurrence of "splashing," with excessive dosage also in the time-sense, viz., beyond some 15 seconds' application in the pig, some 10 seconds in the sheep and calf (Anthony, 1932).

Other species. Reports of the occurrence of skeletal injury or other adverse sequellæ in (experimental) dogs and cats are universally absent, whatever the treatment. Fracture of the spine in the rabbit has been observed by the writer in the present studies with the use of extremely potent square-waves (q.v.) applied in the length of the C.N.S., but only with excessively rapid increment in the current. It was never occurrent with *glissando* increment, nor in any circumstances with current traversing the head according to electroplectic technique. It may be remarked, however, that the rabbit in particular, and rodents in general, may be expected to be uniquely susceptible to this injury, owing to their plantigrade stance and consequent unusual spinal flexion, which renders them atypical.

These various data confirm the obscurity of the issue. It may be wondered how it is that in man increments of the extreme order designated, in both voltage and time, do not result in adverse sequellæ (nor in experimental dogs); whereas in the pig, etc., the reverse is apparently the case. It may be wondered

why no adverse sequellæ at all are on record in the dog and cat. Why is "splashing" so easy in animals (fine petechiation of the lungs in the pig is, in the writer's observations in the abattoir, common); whereas in man three and four convulsions a day for successive days (Milligan), course of treatment exceeding 100 (Moore, 1943), and like heroic measures are reported without consequence, while, as has been seen, the cat has survived up to 95 convulsions at five-minutes intervals. To which may be added that in Hobday's clinical assays, as in the tests made by Dryerre and Mitchell, both on pigs, applications up to at least 30 seconds were without report of skeletal or other manifest injury.

It is not easy to reconcile these data. It would seem that man, the dog, the cat, and the rabbit at least are vitually immune and capable of withstanding a wide variety of electrical treatments, but that animals in the abattoir, pigs in particular, are, relatively speaking, susceptible animals. It is, of course, possible that this is explicable in terms of the idiosyncrasies of species. But the possibility cannot be overlooked that the techniques employed in the abattoir differ and are in some detail defective. And it may be noticed at once that the "immunity" of man, dogs, cats, and rabbits is associated with applications of the current across the cerebrum only. Commonly, in pigs at least, the site of application is more caudal, even behind the ears, and with one technique in use in the abattoir (the "Iwel" electrolethaler), the (three-phase) current is arranged by the disposition of the electrodes to circulate freely about the medulla. Quite apart from the fact that any application of electricity that fails to include the cerebrum is highly suspect from the view-point of anæsthesia, it must be wondered to what extent the designated inclusion of the tracts of the medulla and/or its circulatory centre may account for the skeletal and/or vasopressor effects at issue. Alternatively, other details of the technique require scrutiny.

(7) *Contraindications.* Contraindications for the clinical use of electroplectic anæsthesia would obviously be pre-existing fracture or dislocation; and on account of the effect on blood-pressure, in circumstances where there may be internal hæmorrhage. Cardiovascular disease would have seemed to be a prohibition, but according to Evans (1945), referring to man, electroplexy "can be given with remarkably little danger in cases of serious disease of the cardiovascular system." The scope and limitations of the method are clearly unpredictable logically, and the position *vis-à-vis* pregnancy does not appear to be defined.

Electrotechnical Considerations

(1) *The existing practices.* The current in general use in man and experimentally is ordinary alternating current (a.c.) at 50 c.p.s., from the mains. The mains-pressure is stepped down by transformer and simultaneously earth-disconnected, for obvious reasons of safety. This completes the process, except that the voltage is then variable by rheostat, according to dial readings, and a timing switch calibrated in tenths of a second is provided on the ordinary E.C.T. machine.

Three-phase and rectified single-phase a.c. are also employed in the abattoir, but the advantages of these varieties of a.c. over the ordinary form is obscure.

An alternative form of current, the square-wave, has had employment by Ivy, *et al.* (1931), in the dog, by Arieff (1948) and the present writer in the the rabbit, and has received preferment for clinical use in man by Strauss and McPhail (1946). Such currents are considerably more potent than a.c. (*ca.* *x* 10 or more). Their use accordingly permits of considerable reductions in the current-level, but whether this carries the advantages claimed by Strauss, *et al.*, is something of a moot point. The general action of both forms of current is the same, so that the case is substantially that of substituting a lower dose of a more potent current for a higher dose of a less potent one to procure the same effect, and as declared by Hemphill, *et al.* (*op. cit.*), and, as is amply demonstrated by the previous evidence, only superstition prefers a lower meter reading for its own sake. Indeed, it may be said that the considerably greater potency of the current, carrying as it does the demand for greater care in its use, may be to this extent considered a disadvantage rather than otherwise.

Strauss, *et al.* (*op. cit.*), also employ an unusual method, involving the charge and discharge of a condenser, for administering the shock, and recommend the adoption of the *joule** as the unit of dosage. This seemingly rational suggestion, however, completely ignores the existence and important implications of the " rheobase " (q.v.), and is perhaps adopted by these workers rather on account of the difficulties, with the non-linear decremental flow of square-wave current that is integral with their technique, of attempting a definition of dosage in any other units. This consideration constitutes, in the present writer's view, a serious disqualification of their method. But a feature with even less self-recommendation is the initial high peak of voltage which is equally integral. As these workers themselves point out, a lower dose than they advocate for routine use (25 " joules ")* signifies an initial peak-voltage of the order of 300 V. This is the very reserve of the *glissando* concept and must incur the maximum possible risk of skeletal injury. Their expository statement that " the human brain can stand the transit of momentary peak voltages in excess of 2,000 volts without sustaining damage " is interesting in itself, but seems to disregard the possibilities of alternative injuries.

Finally, as special apparatus is required for the generation of such square-waves, significant advantages in this form of current would require demonstration to justify its preferment to the sublimely simple use of ordinary a.c.

Application of the current in the abattoir to pigs, sheep and calves is by means of tongs (the " electrolethaler ") incorporating an ingenious safety switch which provides that the electrodes can only become elecrically connected if the instrument is closed with force on to a solid object—simple closure is ineffectual. The current then passes so long as such grip is maintained. A second kind of applicator for use specifically in pigs, to which previous indirect reference has been made, and for use with the three-phase current, has a three-pronged con-

*The joule is a unit of electric energy, being the amount of work involved in the transit of one ampere of current through a resistance of one ohm, in one second.

struction, and is conveniently slipped over the occiput. In man, application is effected by means of a head-band or other simple headgear, incorporating the electrodes, which is secured in place in preliminary. An alternative method is simple manual application of the electrodes, suitably insulated and mounted, to the temporal regions, from behind the patient. This is excellently convenient, but for reasons of safety (with this method only) gloves require to be worn by the operator. In all cases the mechanism is then operated by a switch on the timing mechanism. In rabbits, fabric-padded disc-electrodes mounted on a horse-shoe shaped bracket and applied (like headphones inverted) between the ears and eyes, were found to work admirably, and are securely attachable and adjustable in a matter of seconds. The bracket is of Perspex, which provides complete insulation between the electrodes, and also the requisite degree of spring-pressure. In dogs, as witnessed by the writer at one of the large commercial laboratories where electroplexy has been in satisfactory use for some years for purposes of bleeding out, suitable small tongs are employed, after the fashion of the original "electrolethaler" of Mr. C. Golledge, M.R.C.V.S., for euthanasia in small animals.

It requires emphasis that in all these circumstances the current passes at the pre-set maximum voltage *ab initio*. It is also to be noted that in animals (as compared with the human practice) the duration of the application is purely arbitrary and according to the judgment (or misjudgment) of the operator.

Electroplexy in abattoir practice. Doubts have been expressed in the literature as to the fundamental validity of all electroplectic practice for purposes of slaughter (Hertz, 1933; Roos and Koopmans, 1934, 1936; Hume, 1935, etc.). These are considered later. The slaughter of animals is the proper concern of the veterinary profession, and the use of electricity for this purpose lends itself so readily to fallacy and the confusion of issues, that it is appropriate at this juncture to pause to reconsider the situation, as far as it is possible to judge from the evidence. The final court of appeal in this, as in chemical anæsthesia, must be human subjective experience, and, recapitulating, it is seen to be the case :—

(1) That convulsions connote unconsciousness and anæsthesia.

(2) That the situation in default of a convulsion is indeterminate. Subconvulsive dosage can result at the best in only momentary loss of consciousness. Threshold dosage may be associated with a condition of motor-paralysis with consciousness only impaired, pending the onset of a delayed convulsion after a latent period of up to 30 seconds.

(3) Without special precautions, subconvulsive or threshold treatment is inevitable in an unknown proportion of cases, as the result of variations in electrical resistance, susceptibility, size, and the human element, particularly where, as in the case in the abattoir, near-threshold voltages are in use, and the duration of application is arbitrary.

The extent to which the last factor operates was indicated to the writer by observations at one of the larger abattoirs, where the duration of application varied from five to 15 seconds in pigs of comparable size, a variation with no

evident rationale. And it may be added that the situation in respect of this time-factor received very early criticism from Dryerre and Mitchell (*op. cit.*), who pointed out that the true requirements are not likely to be promoted by conditions of high-pressure piece-time work. To this the present writer would add that from the slaughterman's point of view an animal that is only stunned or paralysed is as good as any other, and, indeed, better for purposes of hoisting than one that is fully convulsing. And therefore it requires no stretch of the imagination to anticipate that the slaughterman's discretionary powers in this sense might be intelligently used, and in all innocence, to make the inadequate, stunning dose (threshold or subthreshold dosage) his objective, rather than the full convulsive level. Certainly this is a rational possibility. At all events, there is no doubt that in a small proportion of animals inadequate dosage is involved, though in the writer's impression this is in relation as much to an imperfect application of the electrodes (for various reasons), as to any time-variable. Here, again, however, the human element is involved, and only further justifies the case for the provision of constant-current conditions discussed below, because then even with imperfect contact the same magnitude of current will pass. Furthermore, this would often be associated with burning of the cutis, which would brand and rapidly serve to stigmatise incompetent work, and to the detriment of the slaughterman instead of the pig.

It may be noticed that the realities of the case need not be evident to casual observation in the abattoir, for the course of events is likely to be always much the same. The animals are felled by the current, hoisted and stuck in this condition, and a convulsive pattern of behaviour is seen whether this be the genuine electrogenic convulsion; the delayed convulsion after a latent period in motor-paralysis with at least partial consciousness and sensibility (threshold dosage); or escape movements simulating convulsions, following recovery of somewhat dazed consciousness after hoisting (subthreshold dosage). This last contingency is not necessarily precluded by an absence of protest on the animal's part, because vocalisation can be *inhibited centrally* (as opposed to any motor-paralysis). Pigs are, for example, surprisingly and significantly silent on the ground when ambulatory after shocks which have stunned only lightly, and elicited the usual escape behaviour.

It should be made clear that there is no wish to exaggerate the situation in respect of the standing abattoir procedures. There is no question at all but that these meet the requirements of the majority of the animals, and the position is vastly superior to simple sticking. But it is certain that the full possibilities are not realised, and it is to be remembered that these practices concern not hundreds, but literally many millions, of animals per annum, and that every *one per cent* degree of failure signifies 10,000 animals per specified million slaughtered in offence of the spirit and intention of the Slaughter of Animals Act. No less than that a proper knowledge of the requirements, and corresponding modifications of technique, would prove the 100 per cent certainty that could and should obtain even in the abattoir.

The Technical Requirements, with Special Reference to Clinical Use

The requirements for the use of electroplexy in animals are: (1) Means for the convenient administration of reliably convulsant dosage in every case, and (2) the complete elimination of any existing risk of side-effects. These are the legitimate requirements for slaughtering; they are the essential requirements for clinical use. Both issues are, of course, interdependent.

Considering, first, the question of methods of application, no doubt for pigs and other species of intermediate size, where tongs may be the most suitable form of applicator, the existing principle of design will hardly be bettered. Assuming the use of the method in the adult ox, probably a form of affixable headgear would be a convenient alternative. For the dog and cat (as for the horse, if the question should ever arise) the use of tongs is thought by the writer to have every contraindication. These animals, some dogs in particular, have an instinctive and deep-rooted fear of the approach, let alone their attempted seizure by such devices. This is to add the animals' sometimes savage resentment to a consequent insecurity of application, both diametric opposites of the desirable and constituting total disqualifications. For all but exceptional circumstances a form of pre-applicable headgear—a brow-band, as in man, or such as that used by the writer in the rabbit—would have every recommendation in these animals. (For the horse, assuming again that the question ever arises, a special bridle with rubber bit, incorporating the electrodes in the brow-band, may be envisaged.)

This seemingly simple and trifling issue of the method of application is given some emphasis, because it is such "trifling" details that can determine the success, or failure and consignment to oblivion, of methods in themselves unimpeachable. Thus it may in part explain the failure of the electrolethaler of Mr. Golledge, already referred to, ever to achieve popularity. Tongs were the principle of application here, as at a trial of an electrical method some considerable time ago at one of the leading veterinary clinics, of which the writer has been reliably informed. The occasion seems to have been a pantomime performance, where it was uncertain to the spectators whether it was the dog, the attendant, or the operator, that was to be "electrocuted." There is no excuse for this kind of history, which is, above all with procedures involving so plastic and accommodating a material as electricity, an indictment of nothing but the pathetic inadequacy of the engineering, and in respect of the very "trifling" detail in question. Yet in this particular instance, and typically, the experience appears to have served only to discredit to all observers the (fundamentally sound) method itself.

(To be concluded)

DEVELOPING TENDENCIES IN MASTITIS THERAPY

By R. F. MILTON, B.Sc., F.R.I.C.

THE ravages and wastages caused by the incidence of mastitis in dairy herds are too well understood to warrant much comment. Every farmer knows only too well the cost to him in lost milk yield, and the condition is probably the most frequently encountered by the veterinary surgeon in agricultural practice.

It is, therefore, not surprising that multitudinous attempts have been made to control this disease, and that much painstaking study on the subject has been made by veterinary and other research workers all over the world. It must be admitted, however, that up to more recent times the treatment was far from satisfactory, but that with the advent of modern therapeutic agents greater success has been achieved.

An essential feature in all treatment will always be an understanding of the basic causes, thus leading to a more emphatic attempt to control by preventive measures. By and large, mastitis is a condition of phagacytosis resulting from some irritation in the quarters. In the vast majority of cases the irritation is bacterial in origin, and the concentration of leucocytes locally is the normal mechanism of humeral reaction to disease.

In a few cases, an invading organism may not be detected. Some other irritant factor is then usually the cause, but the vast majority of cases are unquestionably bacterial in origin subsequent to a number of causes. Lowered resistance may be a predisposing factor, particularly following local injury or bruising. Infection occurs by passage up the teat canal by causative organisms, and this is rendered more likely if milking and stripping is incorrectly carried out. Any type of chronic irritation may lead to cellular breakdown in the ducts, and this will render resistance to invading organisms less effective. Bad nutrition may be a predisposing factor, and over-milking with its undoubted effect upon the cow's general health probably also largely contributes. The cow must be kept in mineral and nutritional balance during its functional cycle, and unless sufficient care is taken during the dry period to allow for recovery from drainage upon the animal's economy, the danger of mastitis occurring during the subsequent period will be heightened.

A control programme for the prevention of mastitis has been put forward by McMurray,[1] who recognises four distinct phases in mastitis. Firstly, invasion; secondly, injury to the protecting membranes of the udder; then infection; and, finally, inflammation. He suggested the following procedure for effective control:—

(1) Good sanitation.
(2) Always dry-off cows thoroughly.
(3) Maintain balanced ration.
(4) Periodical veterinary examination.
(5) Use strip cup daily.
(6) Prevent injuries to the udder and teats—which should be examined daily for such signs.

Where injury occurs, first-aid should immediately be carried out, the teat canal, if obstructed, should not be opened with the milking tube, and correct milking procedure should be followed.

The eradication of mastitis has also recently been the subject of a publication by the Technical Development Committee of the N.V.M.A.,[2] wherein the above-mentioned points have been given more emphasis.

Of the various organisms responsible for infective mastitis, the following may be outlined:—

(1) *Streptococcus Agalactiæ*. This organism is said to be responsible for about 70 per cent of the cases of mastitis. The excellent dissertation by Stapleforth[3] on disease caused by this organism is recommended for reference.

(2) *Streptococcus Dysgalactiæ*. Infections from this organism are less common, forming about 5-10 per cent of the cases.

(3) *Streptococcus Uberis*. Even less frequently encountered are cases due to this strain.

(4) *Staphylococcus*. The type of disease due to these organisms is usually quite severe, but normally does not represent more than about 6 per cent of cases, although it may not infrequently be implicated in cases of so-called summer mastitis.

(5) *Corynebacterium Pyogenes*. This organism is usually concerned with summer mastitis, which may become epidemic and spread through the herd with alarming rapidity, sometimes affecting about one-third of the animals. It most frequently attacks dry cows and heifers, and is probably the most serious of the various types.

(6) *B. Coli*. This organism has been identified in about 2 per cent of the cases. It most commonly occurs with chronic lowered resistance of the animal. *B. Coli* (normal habitat in the intestinal tract and the fæces) usually does not penetrate into the udder unless local conditions are very favourable for proliferation.

(7) *Mixed Infections*. Frequently more than one organism is identifiable with a case of mastitis, and secondary infection may always occur as a condition tends to become chronic.

Symptoms

Mastitis may take the acute or the chronic form. In the former cases the onset is sudden, characterised by swelling quarters, pain, heat and hardness. Mammary secretion is often watery and perhaps blood-stained, although in early cases this may not be so. No milk symptoms may be visible until stripping, when blood tingeing may occur. Frequently, in acute cases, the milk may be pus-like in character. These cases may reach a climax and then pass into a chronic condition whereby clinical symptoms are much less marked.

The chronic or light cases may present some difficulty for recognition, and often the diagnosis is only possible by bacteriological examination of the milk. Certain organisms cause a change in the chemical reaction of the milk. (This pH change may be detected using brom cresol purple papers.) Nevertheless,

chronic infection is extremely debilitating to the animal, and if allowed to persist may permanently impair the function.

Treatment

As previously stated, mastitis should always be considered from the preventive angle, and there is not the slightest doubt that in herds where care is taken to maintain balanced diet, hygienic conditions and individual care, the frequency of ravage by mastitis is normally very much less common than in herds where these factors are not paramount. However, when infection has occurred, and becomes recognised, then immediate action should be taken. The first action should be to isolate the affected animal from the rest of the herd.[4] Where the onset has been delayed and intractable induration of the udder observed, the differential diagnosis of tuberculosis must be considered, with notification of the authorities in the usual manner. The obvious dairy precautions should be carefully followed subsequent to the removal of the infected animal, and an attempt made towards decontamination of the milkers' hands, disposal of secretion, disinfection of utensils, floor, apparatus, etc., so as to ensure that spread to the remainder of the herd is avoided. The farmer should be warned against attempting to remove first milk, which is often obviously infected, and then incorporate the remainder with the general milking. He should be equally warned of the danger involved in allowing calves to suckle healthy cows after suckling infected udders.

The dangers of mastitis spread due to cattle movement is too frequently ignored, and farmers should be prevailed upon to desist from sending affected animals to market.

Nevertheless, where definite infection is diagnosed, immediate therapeutic action is called for, and it is interesting to study the various methods and substances which may be used for the purpose.

Chemical Disinfectants. Most chemical disinfectants have been "tried" at one time or another against mastitis, including formalin given as a drench. Needless to say, this latter must be ineffective, since in a blood concentration sufficient to destroy the organisms in the udder it would also be toxic to the host. A variety of substances of the flavine type have had their vogue, but the bulk of evidence suggests that these tend to exacerbate the local irritation and thus lead to an extension of the condition, which remarks equally apply to the majority of chemical agents so employed.[5]

The Sulpha Drugs. The advent of the sulphonamides led to widespread application to the mastitis problem, but it must be admitted that the early expectations have not been borne out to the extent hoped for. The best results were undoubtedly obtained in streptococcal mastitis, but where mixed infections occur, and in the low-grade chronic type, the results were disappointing. It is now generally admitted that the sulpha drugs should only be given in certain types of infection, and that it is best that preliminary tests be carried out to identify the causative organism and to assess its sensitivity against the drug. Dramatic results are still obtained occasionally following the administration of sulphonamides, but these are becoming less frequent. There is no doubt

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that the widespread and indiscriminatory use of sulphanilamide has resulted in strain resistance of organisms to sulphonamides, which is tending to increase, with its manifest effect of lessening certainty of action in mastitic conditions. But sulpha drugs are completely innocuous to certain of the causative mastitis organisms, and with this therapy one can, therefore, only hope to deal with a limited percentage of cases—these becoming increasingly less as resistance develops.

The Antibiotics. Penicillin has been an outstanding success in the treatment of certain forms of mastitis, but resistant organisms are now manifest. Penicillin is most effective in the pure streptococcal infections, particularly *S. agalactiæ*. It is not so effective in the stapylococcus infections, and quite innocuous where *B. coli* is the causative organism. In many cases of mastitis, mixed infection is present, and the result of penicillin treatment is to remove the primary organism but to allow the secondary organisms to proliferate unchecked in a weakened host. Of the resistance developing strains, some of the more common, *Strep. agalactiæ* and *Strep. uberis* are to be mentioned.

Against the tremendous usefulness of penicillin therapy must be mentioned its cost. This antibiotic is often quite ineffective unless given in 100,000 unit dosage so as to maintain a high level of excretion into the mammary ducts. Treatment may be necessary daily for a minimum of three days to be of value, and this does therefore represent a considerable outlay. To avoid unnecessary use of penicillin, a sample of stripping should be tested for organisms sensitivity before a course of this agent is undertaken.

Other Antibiotics. To date, the newer antibiotics, streptomycin, tyrothricin, aureomycin and chlormycetin, have not been sufficiently tried out in mastitic conditions to call for unqualified comment. The comments of Waksman cited in a recent issue of the *J.A.V.M.A.*[6] suggest that streptomycin is ineffective in mastitis complicated by the presence of *B. coli,* certain staphylococcal strains and *Pseudomonas æruginous*. Other workers, however,[7] have reported favourably on its use in mastitis due to *B. coli.* The recent article by Hughes and Farmer[8] on the possible use of streptomycin in veterinary practice clearly indicates the possible sensitive organisms, and, therefore, we may expect this substance to have more widespread application in the future. On the possible uses of the newer antibiotics, an excellent summary is given in the editorial of the *Veterinary Record* of the same issue.[9]

It should be generally emphasised that chlormycetin in particular might have some wider application than penicillin, since its action is against some gram negative as well as gram positive organisms. (Aureomycin has been claimed effective against *S. agalact., B. coli,* and *Strep. uberis.*)

Price is definitely a factor against these substances, and the toxicity of the high-level doses necessary for effectiveness is also to be considered. As with all antibiotics, the possibility of the development of strain resistance is a drawback, but to date this is not manifesting so much with chlormycetin. About the latter drug, it should be mentioned that its synthetic method of preparation makes it potentially a cheaper proposition, and we may look forward to this substance having wider application in the veterinary field.

Bacteriostats. Under this heading we have substances which, while not having direct disinfectant effect, prevent the proliferation of bacteria by interference with their metabolism. The enzyme inhibitors fall in this group, and include such substances as the quarternary ammonium derivatives, pyridinium compounds, certain organic fluorine compounds and some esters of phosphoric acid. In general, while these substances may be of value for the external treatment, they may be too toxic for use where absorption into the general circulation may be a possibility, and therefore of little value in mastitis.

It has been suggested that the newly-developed technique of using iodised oil for the treatment of mastitis may have its explanation in the fact that enzyme inhibition occurs, and so bacteriostic action is obtained.

Iodised Oil Treatment.[10] The use of iodine in the treatment of mastitis is very old and the literature is full of references to this effect. These have been well abstracted by Munch-Peterson.[11] The modern work and modern conception of iodine therapy is primarily due to Saunders,[12] of the Florida Agricultural Experimental Station, who published a series of cases treated by injection into the udder of a solution of iodine in thin mineral oil. The secret of the Saunders technique doubtless lay in the use of an extremely low concentration of iodine. Iodine in normal concentrations is highly corrosive and irritant to the udder membranes, as it tends to form hypiodates, which have an irritating, disinfecting action. The low concentrations are innocuous in this respect, and it is probable that there are formed in the tissues small amounts of iodo derivatives of the unsaturated fatty acids and iodo amino acids which are known to exhibit bacteriostatic action, although the full mechanism is not completely understood. It is also thought that the washing out of the udder with a bland oil has a contributory healing effect, and the direct solubility of the iodine into the fat globules, without previous ionisation, might also be a consideration.

The work of Saunders[12] has been followed up by others, and very favourable comments have been made on its use by Little[13] as chairman of the Mastitis Sub-Committee on Animal Health (N.R.C.).

More recently, work in this country has been carried out by McPherson, of Seale Hayne Agricultural College.[14] Although his published series of cases is small (22, in fact), 19 of the group had already had penicillin treatment, to which they had proved resistant, but cures were obtained in every case with the use of iodised oil. McPherson's animals included the whole range of mastitis conditions, including acute, sub-acute, and chronic cases where all the usual organisms were present.

In addition to McPherson's experimental work, many thousands of animals have now been treated under everyday, practical conditions in various parts of the country with an iodised oil prepared by an electrolytic process (cryozol) with apparently favourable results.

It would appear that iodine in oil can be used in all cases of bacterial mastitis, since it is entirely non-specific in its effect upon the organisms and does not tend to produce resistant strains. It should be emphasised that the iodine in oil fulfils most of the desiderata for mastitis therapy in that it is relatively cheap,

easy to administer, is non-irritant, and is effective in suppressing the infection without interference with normal glandular function. In view of these factors, and the encouraging results so far achieved, this method doubtless warrants more extended trial under practical conditions.

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REVIEWS

ANIMAL FACTS AND FALLACIES, by Osmond P. Breland. London: Faber & Faber, 24, Russell Square, W.C.1. Price 10s. 6d.

PEOPLE are intensely interested in animals. They like to talk and argue about them and appear knowledgeable amongst their fellows. Bits of information, some exact and the result of critical observation, others just founded on fallacy or erroneous hearsay, are passed on, and there is no doubt that if this conglomeration of verbiage could be assembled and analysed a valuable fount of knowledge would be disclosed. Sometimes discussion runs high, and an authority is called in to adjudicate. Nine times out of ten this authority is the local veterinary surgeon, for who should know best the ways of animals and the facts appertaining to their structure and habits.

Pity this poor man when he is approached as oracle or umpire, for if he cannot give a ready and convincing answer his prestige may fall to the utmost limit.

To such a man this book is a "godsend." By perusing its pages he may not only gain personal pleasure, but he will acquire a fund of knowledge which will stand him in good stead and enable him to be profound and interesting in debate. It will also serve as an encyclopædia for those strange, unique and difficult questions which often fall to his lot.

The book will not add to the veterinary surgeon's technical skill, but it will provide many hours of interesting reading to any student of natural history and of the habits and idiosyncrasies of the creatures of land, sea or air.

GREAT SHOW JUMPERS, PAST, PRESENT, AND TO COME, by Pamela Macgregor-Morris. London: George Allen & Unwin, Ltd., Ruskin House, Museum Street. Price 30s.

INTEREST in show jumping is not confined to the select few. As in all other sporting activities, it has a great following amongst the ordinary people who sit and watch, and who have sat on nothing more vital than a horse on a roundabout. . It is these folk who make show jumping on the modern scale possible, for they occupy the ring-side seats and, incidentally, subsidise the sport.

It is doubtful if many horse or agricultural shows could survive unless the spectacle of a jumping event was included in the programme. I have been amazed at the interest displayed in both horses and riders by the ring-siders, and at the technical knowledge which is bandied about quite freely. I have thought that the executives of shows would be doing a good service to the show jumping art, and, incidentally, to themselves if their catalogues could include biographical details of the horses and their riders.

This book fulfils my desire, for it records for all time the heroes, equine and human, of the past. It gives intimate details of the present champions and forecasts those of the future.

Show jumping has been properly organised and regulated since the B.S.J.A. took charge in 1922. It is through the efforts of the Association that show jumping has achieved its present high regard in public esteem.

The ordinary man is able to assess what has to be done, and how it is done, but he has little knowledge of the intimate details associated with the riders and their horses.

Such details are essential if a full and constant enthusiasm is to be evoked. This book supplies that knowledge.

The reader will be thrilled by the many excellent illustrations; he will be intrigued by the biographical details, and from his armchair he may go a long way to become an authority on style and method.

Those who are experts can gain much, but it has a rôle far beyond their desire, for it will educate and delight the greater multitude who sit and watch at the ring-side.

NEW PHARMACEUTICAL RESEARCH CENTRE
I.C.I. Purchase 350-Acre Site

To obtain suitable facilities for their rapidly growing research and administrative organisation, Imperial Chemical (Pharmaceuticals), Ltd. (the pharmaceuticals division of I.C.I.), have purchased 350 acres at Alderley Park, near Manchester.

Building work on the site will, it is hoped, begin in 1951, the first laboratories being scheduled for occupation in about three years. The site will be developed in stages, and will probably take some years to complete. Many of the employees will be highly qualified scientists, to be recruited from all parts of the country. But the main call will be for young men and women as assistants to the scientific staff, and it is naturally hoped to recruit these from such neighbouring areas as Macclesfield, Alderley Edge and Wilmslow. Those who show themselves capable will have opportunities for promotion from the assistants' to the scientists' grades.

No Change in Park's Character

Of the total area of 350 acres, some 150 acres consist of woodland and water, and will not be disturbed. Of the remaining 200 acres of parkland, only a small proportion will be allocated to buildings. The remainder will be used for grazing cattle which will be kept in connection with the research programme. This programme can only be carried out in a clean atmosphere and under first-class agricultural conditions. Any industrialisation on or near the site could only be to the detriment of the whole venture. It can safely be asserted, therefore, that the park will retain its present rural character.

NEW PREPARATIONS

BLACKHEAD IN TURKEYS

The disease is caused by a parasite, *Histomonas Meleagridis*, and it may affect turkeys of all ages, although it is most common in turkeys between the ages of 1-6 months, and the mortality may be as high as 100 per cent.

The Veterinary Science Division of Boots Research Department have been working on this problem for some years in their laboratories and experimental farms at Thurgarton, Notts.

The greatest difficulty in trying to find an effective preventive has been the lack of a reliable method of producing 100 per cent artificial infection. Incidence of natural infection varies from season to season, and because of this it is not possible to draw any scientific conclusions from the treatments used. However, in 1948, Mr. R. K. Farmer and Miss J. Stephenson, of Boots Research Department, discovered a method of infecting turkey poults under defined experimental conditions in such a way that 90-100 per cent of the birds

would die within twelve days of injection. This method was then used for screening drugs for prevention and treatment.

After two years' work on a number of products, they claim that Turk-E-San was found to give protection against the experimental disease (the experimental disease is a much more concentrated and virulent infection than that likely to be picked up under natural conditions).

Turk-E-San is presented in the form of solution tablets for addition to drinking water.

Publishers' Notices

THE BRITISH VETERINARY JOURNAL, with which is incorporated THE VETERINARY JOURNAL, is published monthly, and copy for advertisements should be in the hands of the publishers—Baillière, Tindall and Cox—not later than the 20th of the preceding month, if proof is required. Tel.: Temple Bar 3386.

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